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Content of dry matter, carotenoids and reducing sugars in selected vegetables

Zawartość suchej masy, karotenoidów i cukrów w niektórych warzywach

Summary. The aim of this work was to evaluate 28 carrot genotypes, 5 parsley genotypes, 7 table beet genotypes and 15 onion genotypes and their content of dry matter, reducing sugars and carotenoids. The mean dry matter content in roots of carrot, parsley, table beet and onion bulbs was 13, 24, 16 and 13% and the content of reducing sugars was 104, 93, 111 and 90 g/kg, respectively. Mean carotenoids content in roots of carrot and table beet was 86 mg/kg and 2 mg/kg, respectively. Significant positive correlations (r = 0.43–0.86) between dry matter and sugar content in all species were found.

Key words: vegetable, genotype, sugars, dry matter, carotenoids

INTRODUCTION

Vegetables belong to the nutritionally valuable food sources. Increase of their consumption is thus beneficial to a healthy diet. Different vegetable species have different nutritional composition. The content of nutritional compounds can be affected by many external or internal factors. One of the most important influencing factors is the cultivar [Alasalvar *et al.* 2001]. The content of nutritional components in vegetables found by different authors differ greatly. The mean content of dry matter, sugars and carotenoids in four dietetically important vegetables cultivated in recent studies in different countries is given in Table 1.

The aim of this work was to compare the content of nutritional compounds mentioned above in several cultivars and breeding lines of carrot, onion, table beet and parsley grown in Northern Czech Republic.

Table 1. Mean content of selected nutritional compounds in four vegetables

Vegetable	Dry matter g/kg	Sugars g/kg	Carotenoids mg/kg	References
Beet	123[7] 135[8]	67.6[8] 96[7]	200 μg caroten[8]	[1]Alasalvar *et al.* [2001] [2]Leclerc *et al.* [1991] [3]Lachman *et al.* [2000] [4]Ramesh *et al.* [1999] [5]Rosenfeld *et al.* [1998] [6]Rosenfeld *et al.* [1999] [7]Rubatzky [1999] [8]USDA [2007]
Carrot	97[2] 117[8] 122[7]	37.7–67[5] 48[8] 39.3–42.9[6] 19.6–41.1[1] 99[7]	40–142[5] 121[8] 136–854[3] 1780[4]	
Onion	110[8] 202[7]	42.4[8] 168[7]	10 μg caroten[8]	
Parsley	120[7] 123[8]	8.5[8] 23[7]	50.5 caroten[8]	

MATERIAL AND METHODS

All vegetables were grown in the field conditions in Svijanský Újezd (North Czech Republic). Assortment of 7 cultivars of table beet (*Beta vulgaris* var. *conditiva*), 28 genotypes of carrot (*Daucus carota*), 15 genotypes of onion (*Allium cepa*), and 5 genotypes of parsley (*Petroselinum crispum* var. *radicosum*) was selected for evaluation in the experiment. A list of evaluated genotypes is shown in the part with results. Most genotypes originated from Moravoseed Ltd. (CZ) with only few exceptions (carrot cv. Nebula F1 from SVS Holland B.V., NL, cv. Presto from Vilmorin S.A., F and beet cv. Burpees Golden from Johnny´s, USA). The common cultivation technology was used and the dates of sowing, harvest as well as plant spacing are presented in Table 2.

Tab. 2. Important data of vegetable cultivation

Vegetable	Sowing date	Harvest	Plant spacing (m)
Beet	8th June 2007	8th October 2007	0.45 × 0.10
Carrot	25th April 2007	10th October 2007	0.75 × 0.07
Onion	6th March 2007	20th August 2007	0.45 × 0.10
Parsley	25th April 2007	10th October 2007	0.75 × 0.07

Carrot and parsley were grown in double-rows. A different sowing date was only in case of carrot ´Stupická´ – on 10th June 2007 and cv. ´Rondo´ on 2nd July 2007. Fertilization was made with NPK (15% N, 15% P, 15% K) in a dose of 500 kg/ha. Moreover foliar fertilizer Wuxal (8% N, 8% P, 6% K) at the concentration of 0.1% and in the dose of 300 l/ha was applied 5 times during the season.

Beet fertilization was similar to carrot technology: 500 kg/ha NPK. Also, three foliar fertilizations with Wuxal were made in the same dose.

Onion was sown on 6th March 2007, but cv. ´Augusta´ and ´Hiberna´ on 10th August 2006. Fertilization dose was 500 kg NPK/ha. During cultivation 200 kg/ha of Cererit

(8% N, 13% P, 11% K) and 70 kg/ha of ammonium nitrate with limestone (27% of N) were applied.

Samples were analysed directly after harvest. Samples were prepared from at least 5 plants of the appropriate size and developmental stage. Carrot, parsley and table beet roots were hand washed in tap water, onion bulbs were dry cleaned from the soil remains. The vegetable was in „kitchen-ready" stage. For preparation of samples the complete root or bulb of harvest ripeness were taken. Homogenisation of samples was made, after final washing of samples in distilled water, in a stainless mixer Braun (Braun, D). Analyses of all samples were made in 3 repetitions. There were used common digestion procedures.

Dry matter of fruits and bulbs was determined after drying the samples in oven Sterimat 574.2 (BMT, Czech Republic) at 105°C till the samples reached a constant weight. Reducing sugars content was determined by iodine titration according to the Rebelein method. The content of total carotenoids was analysed by spectrometry at 440 nm wavelength in the spectrometer Jenway 6100 (Jenway, Great Britain). Samples for carotenoids analysis were extracted by the IKA extractor (IKA, Germany) during 8 extraction cycles (total time 160 minutes) in acetone. Elimination of light was assured by the use of dark lab glass and other lab equipment. The samples were purified by centrifugation before measurement. Data are presented for fresh weight. Analyses were repeated twice.

Variance analysis was used followed by Sheffe test at 95% of probability. Correlation analysis was based on Pearson-Spearman-Kendall matrix. All data were computed in Unistat statistical package (Unistat, Inc., USA).

RESULTS AND DISCUSSION

Dry matter

Roots of table beet contained about 160 ±20 g of dry matter in 1 kg of fresh mass. While the lowest content was found in cv. Monika (133 g/kg), cv. Káhira reached 185 s/kg. Data are slightly higher if compared to the Rubatzky [1999] or USDA [2007]. A significant effect of genotype on dry matter content was also detected (Table 3).

Mean content of dry matter in carrot roots was 132 ±17 g/kg. The range was from 105 g/kg (cv. Presto) to 164 g/kg (cv. Cortina F1). Leclerc [1991] found 97 g/kg, which is a relatively low value in comparison to these data. Dry matter content is strongly influenced by climate (temperature, sun radiation) and such an effect could play a crucial role in dry matter formation. There was detected asignificant effect of cultivar on the dry matter content and 28 evaluated genotypes formed 10 statistically different groups, as shown in Table 4.

Onion bulbs were characterised by mean content of 130 ±21 g/kg. The range was from 71 g/kg (cv. Globo) to 162 g/kg (cv. Stuttgart). The effect of genotype was confirmed by 9 different groups (Table 5). The content of dry matter was close to those published by USDA [2007].

Parsley roots showed the mean content of 237 ±20 g/kg and the interval varied between 212 g/kg (cv. Hanácká) to 263 g/kg (cv. Olomoucká). A statistical difference among cultivars was found.

The level of dry matter content is affected by genotype [Rosenfeld *et al.*, 1998]. Such effects could play an important role influencing the observed results.

Reducing sugars

Sugar content in beet roots was 111 ±18 g/kg. The range was within the interval 88 g/kg (cv. Monika) and 135 g/kg (cv. Monorubra). While the lowest content was close to the level of 68 g/kg according to the USDA [2007], the highest one was nearly two-fold higher.

The content of sugars in carrot roots was 104 ±12 g/kg. Cv. Presto showned the level of 76 g/kg only, while cv. FV 124 g/kg. A significant difference among genotypes was confirmed. There were found 13 different genotype groups, according to the sugar content. Total sugars content was higher if compared to the Alasalvar *et al.* [2001].

In onion bulbs mean sugar content was 90 ±18 g/kg. The minimum was shown by cv. Globo (50 g/kg) and maximum by cv. Stuttgart (124 g/kg). Statistical significance of genotype was found. Literature data are highly variable, probably according to the climate and fertilisation of the culture. Considerably high differences in onion are based on onion cultivar type also. While cv. Globo is suitable for fresh salad use, genotypes such as cv. Stuttgart are recommended for long-time storage. In such a situation high dry matter and sugar content is necessary to assure good storability of bulbs.

The mean content in parsley roots was 93 ±9 g/kg. The lowest content was found in cv. Hanácká (76 g/kg) and the highest content in cv. Alba (102 g/kg). The effect of genotype was significant. The content of sugars was relatively high to the few literature data [Rubatzky 1999] publishing sugar content in parsley.

Total carotenoids

The content of total carotenoids is important in carrot. The mean value was 86 ±25 mg/kg and it fits to the formerly published data of many authors. The lowest carotenoids content was in breeding line FUK (42 mg/kg) and the highest one in cv. Cortina (168 mg/kg). Statistical analysis detected 6 cultivar groups (Table 4).

Analyses of carotenoids was also made in beet assortment, where the mean content was 2 mg/kg only. Such a low level corresponds to the amount of 0.2 mg of carotene [USDA, 2007].

Tabela 3. Mean content of dry matter and reducing sugars in beet roots

Cultivars	Dry matter, g/kg			Cultivars	Sugars, g/kg		
Monika	133	±0.5	a	Monika	88	±0.2	a
Alexis	137	±0.3	a	Alexis	91	±0.0	a
Červená	153	±0.3	b	Burpees	102	±4.6	a b
Bona	159	±0.5	c	Kahira	109	±5.2	b c
Burpees	172	±2.0	d	Červená	120	±0.3	c d
Monorubra	183	±1.0	e	Bona	132	±0.3	d
Kahira	185	±1.0	e	Monorubra	135	±0.3	d

Note: Means are followed by standard deviation.
Different letters indicate significant differences.

Table 4. Mean content of dry matter, reducing sugars and carotenoids in carrot roots

Cultivars	Dry matter, g/kg			Cultivars	Sugars, g/kg			Cultivars	Carotenoids, mg/kg		
Presto	105	±2,6	a	Presto	76	±2,0	a	Fuk*	42	± 1,2	a
Nantes	107	±1,9	a b	K6*	88	±0,6	a b	Presto	61	± 3,5	a
Favorit	109	±0,7	a b	Amo F 1	92	±0,3	b c	Amo F 1	62	± 2,6	a
Amo F 1	112	±2,6	a b c	Karotina	92	±1,2	b c	Olympus	64	± 9,8	a b
Napoli F 1	114	±0,6	a b c d	Cidera	92	±1,2	b c	Napoli F 1	68	± 2,3	a b
Cidera	118	±2,9	a b c d	Nantes	93	±0,3	b c	Nantes	69	± 4,6	a b
Karotina	118	±1,4	a b c d	Vita longa	93	±1,2	b c	Stupická	72	± 2,6	a b c
Nantes 2+4	120	±2,0	a b c d	Mon	94	±1,7	b c d	Sylva	73	± 0,6	a b c
Mon	120	±0,9	a b c d e	Napoli F 1	95	±1,2	b c d e	Karotela	74	± 2,0	a b c
AxNan F 1	124	±2,3	a b c d e f	AxFiv F 1	98	±0,9	b c d e f	Korina	74	± 3,2	a b c
Karotela	124	±2,0	a b c d e f	Sylva	100	±1,5	b c d e f g	Katrin	75	± 2,3	a b c
Darina	124	±2,3	a b c d e f	Cortina F 1	101	±1,8	b c d e f g h	Bengala F 1	79	± 2,6	a b c d
Olympus	125	±0,9	b c d e f	Nantes 2+4	102	±1,7	c d e f g h	AxFiv F 1	80	± 3,2	a b c d
Fuk*	130	±1,4	c d e f g	Karotela	103	±0,3	c d e f g h	Rondo	80	± 4,6	a b c d
Vita longa	131	±1,4	d e f g	AxNan F 1	104	±1,5	c d e f g h i	Favorit	81	± 3,5	a b c d e
Katrin	131	±2,6	d e f g	Nantes 2/1	107	±0,3	d e f g h i j	Mon	81	± 8,1	a b c d e
Bengala F 1	132	±1,5	d e f g	Katrin	108	±0,0	e f g h i j k	Nebula F 1	86	± 4,3	a b c d e
Sylva	139	±0,5	e f g h	Korina	108	±0,6	e f g h i j k	Darina	86	± 3,5	b c d e
K6*	139	±2,3	f g h	Stupická	110	±0,3	f g h i j k l	Karotina	89	± 7,5	b c d e
AxFiv F 1	140	±2,0	f g h i	Bengala F 1	112	±1,5	g h i j k l m	FV*	90	± 5,5	b c d e
Rondo	143	±0,3	f g h i	Tinga	113	±1,2	g h i j k l m	Nantes 2/1	93	± 2,6	b c d e
Nantes 2/1	148	±1,2	g h i j	Olympus	114	±1,8	h i j k l m	Nantes 2+4	93	± 3,5	b c d e
Stupická	148	±2,6	g h i j	Rondo	117	±0,3	i j k l m	Cidera	101	± 5,5	b c d e
FV*	152	±2,9	h i j	Fuk*	117	±1,7	i j k l m	Vita longa	114	± 3,8	c d e
Nebula F 1	152	±1,5	h i j	Darina	119	±2,6	j k l m	AxNan F 1	115	± 0,9	c d e
Korina	158	±1,7	i j	Nebula F 1	121	±2,7	k l m	K6*	119	± 7,5	d e
Tinga	164	±2,4	j	Favorit	122	±2,3	m	Tinga	124	± 6,9	e
Cortina F 1	164	±2,9	j	FV*	124	±0,3	m	Cortina F 1	168	± 4,6	f

Note: Means are followed by standard deviation. Different letters indicate significant differences.

* Breeding line

Table 5. Mean content of dry matter and sugars in onion bulbs

Cultivars	Dry matter, g/kg			Cultivars	Sugars, g/kg		
Globo	71	±1.4	a	Globo	50	±0.3	a
NŠL 12/3*	116	±0.8	b	Signum	68	±0.2	b
Signum	116	±0.2	b	Všetana	82	±3.5	c
NŠL 12/5*	118	±0.2	b c	NŠL 12/3*	82	±0.6	c
Olina	121	±0.3	b c	NŠL 12/5*	82	±0.0	c
Augusta	126	±0.8	c d	Olina	85	±0.2	c d
Tandem	130	±0.9	d e	Augusta	86	±0.3	c d e
Všetana	131	±0.3	d e f	Hiberna	89	±0.2	c d e f
Grenada	132	±1.6	d e f	Grenada	91	±0.3	c d e f
NŠL OC*	137	±0.3	e f g	Alice	95	±0.2	d e f
Karmen	139	±0.3	f g	Tandem	97	±0.0	d e f
Alice	141	±1.2	g h	Karmen	98	±0.3	e f
Hiberna	147	±2.9	h	NŠL OC*	100	±3.5	f
NŠL 12/6*	157	±0.9	i	NŠL 12/6*	121	±4.0	g
Stuttgart	162	±0.2	i	Stuttgart	124	±0.2	g

Note: Means are followed by standard deviation. Different letters indicate significant differences.
*Breeding line

Table 6. Mean content of dry matter and sugars in parsley roots

Cultivars	Dry matter, g/kg			Cultivars	Sugars, g/kg		
Hanácká	212	± 0.5	a	Hanácká	76	± 0.2	a
Alba	222	± 2.0	b	Konika	92	± 0.2	b
Konika	232	± 2.0	c	NŠL OB*	94	± 0.6	b
NŠL OB*	254	± 0.4	d	Olomoucká	101	± 1.7	c
Olomoucká	263	± 0.9	e	Alba	102	± 4.9	c

Note: Means are followed by standard deviation.
Different letters indicate significant differences.
*Breeding line

Correlation analysis

Correlation effects are displayed in Figures 1–4. Analysis of mutual correlation of the content of analysed compounds resulted in positive correlation between dry matter content and reducing sugars. The range of correlation coefficient was within an interval of r = 0.43 in carrot, r = 0.46 in parsley, r = 0.59 in table beet up to r = 0.86 in onion. All these correlations were statistically significant at 95% probability. A correlation of carotenoids to the dry matter or to the reducing sugar content was not detected.

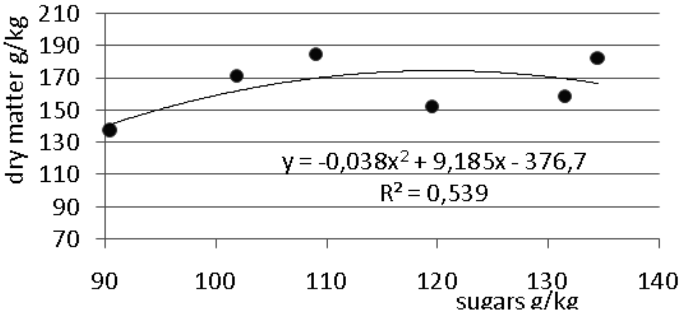

Fig. 1. Correlation of dry matter and sugars – beet

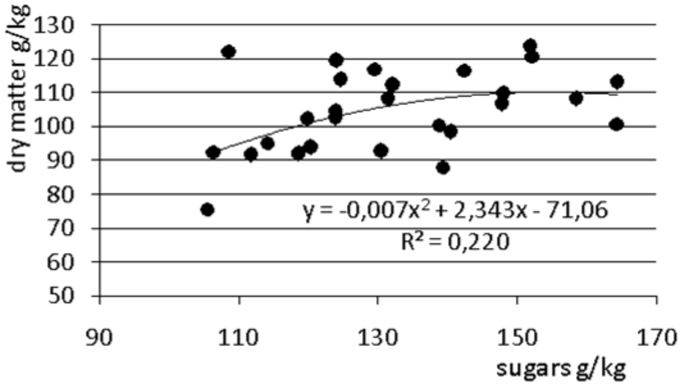

Fig. 2. Correlation of dry matter and sugars – carrot

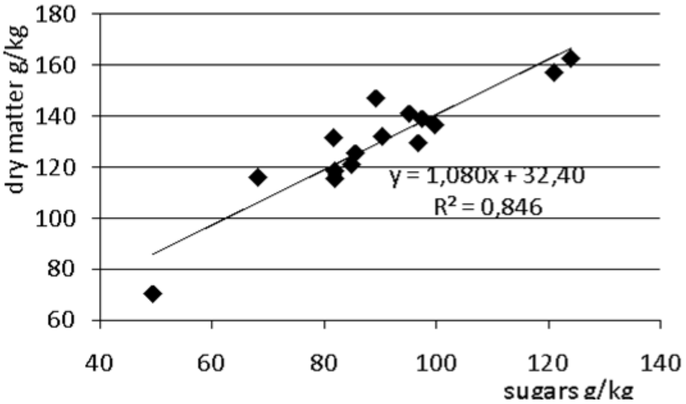

Fig. 3. Correlation of dry matter and sugars – onion

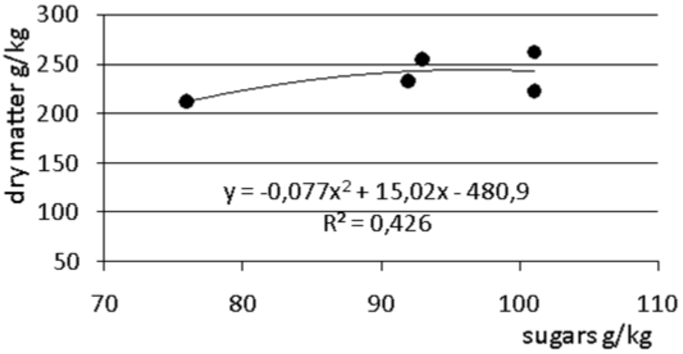

Fig. 4. Correlation of dry matter and sugars – parsley

CONCLUSIONS

The results of screening showed important differences between vegetable cultivars in their nutritional quality. Significant differences between the genotypes of all tested species were found. In some cases, the highest values measured were more than double of those of the lowest values, in cultivars from the same vegetable species.

The data confirmed the correlation between dry matter and the levels of reducing sugars. This can prolong the shelf life of such vegetables, with commercial implications.

Information about nutritional quality is also an important issue for plant breeders to consider when making their selections. The breeding of new genotypes can in this way contribute to a more nutritious human diet and, in some cases, such as where sugar content is involved, can support taste, popularity and consumption of vegetables.

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